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INTRODUCTION

A frequent question asked by beef cattle producers is what supplement should be used. Prior to asking this question, it should be determined if a supplement is necessary. To answer this question, the nutrient requirements of the animal to meet the desired production level must be established. Next, it should be determined if current feed resources will meet these needs. It may be possible to shift grazing practices or to adjust feeding levels and meet the requirements. Once it is established that a supplement must be used, then the supplement that will improve the utilization of the base diet should be selected.

With the wide array of supplements that are marketed, the different methods of feeding, and the differences in price and ingredients, choosing a supplement can be difficult. A good understanding of the principles of nutrition and digestion by beef cattle, the quality of the forage to be supplemented, the supplement composition, and associative effects that the supplement has on the forage will aid in determining the supplement that will provide the most benefit. Readers should refer to the previous paper in this proceedings for a discussion on basic nutrition of ruminants.

This paper is written with the assumption that the primary component of the diet is forage. The data presented will be discussed assuming that the goal is for optimum utilization of the forage to meet the nutrient requirements of the animal at a given production level. This paper will also focus on the aspects of interactions of nutrients that are available to the microorganisms in the rumen and the resulting associative effects of the supplements on forage utilization. Economics of the feeding program will not be considered, however depending on the price of the forage and the supplement, it may be more economical to disregard the supplement's affect on forage utilization and to provide a majority of the nutrients through the supplement.

ASSOCIATIVE EFFECTS OF FEEDS

In formulating diets for beef cattle, associative effects of feeds are ignored, and it is assumed that each feed will contribute the amount of nutrients without interfering with other feeds. For example, formulating a diet using 20 pounds of hay containing 90% dry matter, 45% TDN, and 5% protein and 4 pounds of corn containing 88% dry matter, 90% TDN, and 10% protein would result in feeding 22.3 pounds of dry matter, 12 pounds of TDN, and 1.3 pounds of TDN. The problem with this approach is that often we forget that much of this feed will be altered by the organisms in the rumen before it is absorbed by the animal and that the energy values have been derived with animals on a high percentage of that nutrient. In actuality, with the above diet, we may have more or less TDN and protein absorbed by the animal, depending on how the forage and corn interact with the microbes in the rumen. This interaction of two or more feeds are called associative effects. These effects can either be positive, negative, or no effect, resulting in improved, decreased, or no effect on utilization of the overall diet.

To understand associative effects, it is essential to understand the chemical makeup of the different portions of the diets and how these portions are acted on by the ruminal microorganisms. The primary energy source in diets of ruminant animals are carbohydrates. All feeds contain both structural carbohydrates and non-structural carbohydrates. Structural carbohydrates or neutral detergent fiber function in the plant to give support, while non-structural carbohydrates are used to in metabolism. It is very important to understand the difference between these two types of compounds, and how they are metabolized by the microorganisms in the rumen. Structural carbohydrates are primarily cellulose and hemicellulose and make up a large portion of the carbohydrate fraction of forages and other roughage. The digestion of structural carbohydrates is conducted in the rumen by the microorganisms, and depending on the complexity of the chemical bonding, usually the rate that they are digested is fairly slow. Little, if any of these compounds would be available to the animal with the aid of the microorganisms. In contrast, non-structural carbohydrates are composed of starches, sugars, and other simple carbohydrates. These compounds can be digested by the microorganisms in the rumen or can be digested by the animal. The rate of digestion of these compounds is much faster than for structural carbohydrates, and the percentage that is digested is higher than with structural carbohydrates. Grains are high in non-structural carbohydrates.

Knowing forage maturity is important when considering associative effects of feeds. As forages mature, the percentage of structural carbohydrates increase with a corresponding decrease in the non-structural carbohydrates. The digestibility of the structural carbohydrates also decreases as forages mature. In a recent study conducted at the University of Wyoming using native meadow forages harvested at two different maturities, the digestibility of the structural carbohydrates was 45% in the late- cut or mature forage compared to 60% in the early-cut forage.

LOW-PROTEIN MATURE FORAGES

Protein supplementation of mature, low-quality, low-protein forages result in a positive associative effect. Data from a research study conducted at the West Central Research and Extension Center in Nebraska (Sanson et al., 1990) is shown in Table 1. The forage used in this study was a native meadow hay containing 4.3% protein. The trial was conducted with steers, however the data have been modified to simulate a 1000-pound cow. Feeding a protein supplement containing soybean meal and corn gluten meal (low in non-structural carbohydrates) increased forage dry matter intake by 3 pounds, increased TDN of the forage by 3.9%, increased TDN of the diet by 5%, increased TDN intake from the forage by 2 pounds and increased diet TDN intake by 3.1 pounds. The third column of Table 3 contains the estimated amount of TDN the animals would have consumed disregarding associative effects. Note that only one extra pound of TDN intake would be estimated from this approach and that this approach does not account for any increase in forage intake or from forage digestibility.

Table 1. Dry matter and TDN intake of a low-protein mature forages supplemented with a protein low in non-structural carbohydrates[a]

	No supplement[b]	Actual protein supplement[b]	Estimated protein supplement[c]
-------------- Mature low-quality forage, 4.3% protein ---------------			
Forage dry matter intake, lbs	18	21	18
Diet dry matter intake, lbs	18	23	20
Forage TDN, %	38.9	42.8	38.9
Diet TDN, %	38.9	43.9	43.7
Forage TDN intake, lbs	7.0	9.0	7.0
Diet TDN intake, lbs	7.0	10.1	8.7

[a]Data adapted for a 1000-pound cow from Sanson et al. (1990).
[b]Actual data from trial.
[c]Data estimated using data from non-supplemented group.

This study indicates that feeding a protein supplement low in non-structural carbohydrates results in a positive associative affect by increasing forage intake and forage digestibility. There are numerous other published research articles using protein supplements low in non-structural carbohydrates that agree with the findings of this studies. These data are results from mature low-protein forages when supplemented with protein supplements low in non-structural carbohydrates. Forages containing adequate ruminal degradable protein in relation to its energy content will probably not result in a positive associative affect from similar protein supplementation.

With low-protein mature forages, supplements high in non-structural carbohydrates result in different associative effects regardless of protein content of the supplement than protein supplements formulated with ingredients that are low in non-structural carbohydrates. Table 4 shows data from a trial with steers consuming a low-protein (5.2% protein) mature hay and supplemented with whole corn (high in non-structural carbohydrates) conducted at the West Central Research and Extension Center in Nebraska (Sanson and Clanton, 1989). These data have been modified to represent a 1000-pound cow. Animals receiving no supplement consumed 17 pounds of a forage containing 44.0% TDN, resulting in a TDN intake of 7.5 pounds. Feeding the low level of corn did not alter forage intake and increased forage TDN content to 45.1%, resulting in 7.7 pounds of TDN intake from the forage and 10 pounds of TDN from the diet. Estimated TDN intake of this diet would be 10.1 pounds, thus the associative effect of corn at this level of feeding was only slightly negative. With the medium level of corn supplementation, hay intake was 2 pounds less, and the TDN content of the forage decreased 5.9%. Diet TDN intake from the forage was only 5.7 pounds, and diet TDN intake was 9.6 pounds, .4 pounds less than with the low level of corn supplementation. The estimated TDN intake of this diet was 11.5, thus a large negative associative effect occurred with corn supplementation at this level. With the high level of corn supplementation, forage intake was 2 pounds lower than the non-supplemented group and the TDN content of the forage decreased to 35.6%, resulting in only 5.3 pounds of TDN from the forage. Diet TDN intake of this diet was 11.7 pounds, the highest of any of the treatments, however the estimated TDN intake was 13.4, overestimating the TDN intake from the diet by 2.7 pounds. With the medium and high level of corn supplementation, TDN intake from the supplement 41 and 55% of the diet intake and the corn had negative associative affects on the utilization of the forage.

Table 2. Effect of corn on dry matter and TDN intake of a mature low-protein (5.2%) hay[a]

	No supplement	.2 4 lbs CP 2.5 lbs corn	.48 lbs CP 5.0 lbs corn	.72 lbs CP 7.5 lbs corn
Forage dry matter intake, lbs	17	17	15	15
Diet dry matter intake, lbs	17	19	19	22
Forage TDN, %	44.0	45.1	38.1	35.6
Diet TDN, %	44.0	51.0	50.8	53.2
Forage TDN intake, lbs	7.5	7.7	5.7	5.3
Diet TDN intake, lbs	7.5	10.0	9.6	11.7

[a]Data adapted for 1000-pound cow from Sanson and Clanton, 1989.

In another study conducted with steers consuming a mature, low-protein (4.3% protein), native meadow, mature forage receiving supplements that provided equal amounts of soybean meal but increasing levels of corn (Sanson et al., 1990), a similar trend was observed (Table 3). The effects of the protein supplement was discussed earlier. The low level of corn supplementation increased TDN intake by one pound of TDN compared to the protein supplementation. This was .6 pounds of TDN less than would have been estimated, implying a slight negative associative effect. With the supplement supplying corn at .5% of body weight, the diet TDN intake was 1 pound less than the group receiving the supplement supplying corn at .25% of body weight, implying that a decrease in either forage or supplement utilization or both was large enough to offset the additional 2.2 pounds of TDN supplied by the additional corn.

Similar effects of corn were observed in a study conducted by researchers at South Dakota State University (Namminga et al., 1993) where a mature low-quality (5.6% protein) prairie hay was supplemented with increasing levels of corn. The supplement containing no corn resulted in a positive associative effect on forage utilization, increasing hay intake by 4 pounds and forage TDN by 4%. Feeding 3.3 pounds of corn (3 pounds of TDN) decreased hay intake compared with the protein supplement, and resulted in only .6 pounds more TDN intake from the diet. Increasing the level of corn supplementation to 6.6 pounds (6 pounds of TDN) only increased the diet TDN intake by .8 pounds compared to the low level of corn supplementation. Both corn supplements decreased forage TDN content and resulted in 36% and 65% of the diet TDN being furnished by the supplement.

Table 3. Effect of corn-soybean meal supplements on dry matter and TDN intake of a mature low-quality forage (4.3% crude protein)[a]

	No supplement	1.1 lbs CP 0.0 lbs corn	1.1 lbs CP 2.5 lbs corn	1.1 lbs CP 5.0 lbs corn
Forage dry matter intake, lbs	18	21	20	16
Diet dry matter intake, lbs	18	23	24	22
Forage TDN, %	49.5	54.5	54.5	52.0
Diet TDN, %	49.5	55.7	59.2	60.0
Forage TDN intake, lbs	8.9	11.5	10.9	8.3
Diet TDN intake, lbs	8.9	12.8	14.2	13.2

[a]Data adapted for 1000-pound cow from Sanson et al., 1990.

Table 4. Dry matter and TDN intake of a mature low-quality forage (5.6% protein) when supplemented with corn-soybean combinations[a]

	No supplement	.6 lbs CP 0.0 lbs corn	.9 lbs CP 3.3 lbs corn	1.1 lbs CP 6.6 lbs corn
Forage dry matter intake, lbs	15	19	16	13
Diet dry matter intake, lbs	15	20	20	20
Forage TDN, %	39	43	40	33
Diet TDN, %	39	47	50	54
Forage TDN intake, lbs	5.8	8.2	6.4	4.3
Diet TDN intake, lbs	5.8	9.4	10.0	10.8

[a]Data adapted for 1000-pound cow from Namminga et al, 1993.

These studies point out associative effects supplements have on forage utilization. With low-protein mature forages, protein supplements containing low amounts of non-structural carbohydrates tend to have a positive associative effect on utilization of the forage, while supplements, regardless of protein contents, that contain a high percentage of non-structural carbohydrates have a small to a large negative associative effect depending on the amount of the non-structural carbohydrates fed. It appears that corn fed at or less than 2.5% of body weight has a minimal negative effect on forage utilization. At levels above 2.5%, negative effects are much larger.

Data presented in Tables 1, 2, 3, and 4 have been adapted from metabolism studies; because of some management practices used in these studies, they may not totally reflect what occurs under a normal production situation. Data from a production study conducted at the Gudmundsen Sandhills Laboratory near Whitman, NE, demonstrate this point (Table 5). Cattle were fed either .63 pounds of protein from a 32% protein supplement that supplied 1.6 pounds of supplemental TDN, .63 pounds of protein and 2.6 pounds of TDN from a protein supplement plus 3 pounds of ear corn or .28 pounds of protein and 2.6 pounds of TDN from 3.5 pounds of ear corn. Cows grazed dormant native range during the 112-day period. Cows receiving the 32% protein supplement gained 15 pounds while cows receiving 3 pounds of ear corn lost 40 pounds. The cows receiving the 3.5 pounds of ear corn lost 121 pounds, however these cows received less supplemental protein than the cows on the other treatments. The metabolism studies in Tables 2 and 3 indicate that corn at levels at .25% of body weight or lower should not decrease forage utilization, however in this study the weight change of cows fed 3 pounds of ear corn (.26% of body weight) was 55 pounds below that of cows receiving only the protein supplement. Part of this difference may be due to the protein source. The escape protein of ear corn would be expected to be higher than the 32% protein supplement. However, part of this response may be due to the forage quality and grazing patterns of the cows compared to the those of animals on digestion studies.

Table 5. Effect of ear corn on performance of cows grazing dormant native sandhills range[a]

	.63 lb CP 0.0 lbs ear corn	.63 lbs CP 3.0 lbs ear corn	.28 lbs CP 3.5 lbs ear corn
Supplement dry matter, lbs	2.0	4.0	3.5
Supplement TDN, lbs	1.6	2.6	2.6
Initial weight, lbs	1158	1154	1164
Weight change, lbs	15[b]	-40[c]	-121[d]

[a]Adapted from Rush et al, 1986.
[bcd]Means within a row with different superscripts differ ($P < .05$).

Data from a production study conducted at the South Dakota State University Range and Livestock Research Station (Pruitt et al., 1993) indicates little benefit from higher levels of corn supplementation (Table 6). In this trial, cows received either .72 or 1.4 pounds of protein with no corn or 7 to 8 pounds of corn while grazing native winter range for 60 days. Seven pounds of corn did not increase weight gain of cows compared to cows receiving only protein from soybean meal. When protein supplementation was increased to 1.4 pounds, cows receiving soybean meal gained 45 more pounds of weight, while cows receiving soybean meal plus 5.5 pounds of corn gained an additional 21 pounds. However, for the 60-day trial, 330 pounds of corn was required for the extra 21 pounds of gain.

Table 6. Effect of corn-soybean combinations on performance of cows grazing dormant native range at Cottonwood, SD[a]

	.72 lb CP 0.0 lbs corn	.72 lbs CP 7.0 lbs corn	1.4 lbs CP 0.0 lbs corn	1.4 lbs CP 5.5 lbs corn
Supplement dry matter, lbs	1.7	7.4	3.1	7.6
Supplement TDN, lbs	2.4	6.5	4.8	6.6
Initial weight, lbs	1126	1124	1120	1124
Initial condition score	5.6	5.7	5.7	5.7
Weight gain, lbs	48[b]	47[b]	93[c]	114[d]
Condition score change	.1[b]	.3[bc]	.4[bc]	.5[c]

[a]Adapted from Pruitt et al, 1993.
[bcd]Means within a row with different superscripts differ ($P < .05$).

Some byproducts of the milling industry offer feeds that are low in non-structural carbohydrates, and contain structural carbohydrates that have a high digestibility. A study conducted at Oklahoma State University comparing soybean hulls to soybean meal supplements is shown in Table 7 (Marston et al, 1992). In this study, gestating cows were supplemented 1.4 pounds of protein with supplements containing different combinations of soybean hulls and soybean meal while grazing dormant native prairie. Cows receiving the supplement containing high levels of soybean hulls consumed less forage, however little difference was observed in the forage TDN content of the forage and these cows gained 39 more pounds than cows that received the supplement low in soybean hulls. Soybean hulls do not appear to have a negative associative effect on forage digestibility.

Researchers at Oklahoma State (Ovenell et al, 1989; Cox et al, 1989) also evaluated wheat mids as a supplement for fall and spring calving cows grazing dormant native prairie. Cows received 1.2 pounds of protein and .8, 2.2, 4.9, or no wheat mids. The spring calving cows increased weight gain as level of wheat mids increased in the supplement. In contrast, the cows that had calves on them during the supplementation period all lost weight, with no difference in weight loss. The calves on these cows receiving the higher levels of wheat mids were 11 to 15 pounds heavier at the end of the supplementation period (difference was not significant). Any extra energy supplied by the supplement may have went to increase milk production instead of increasing cow weight.

Table 7. Effect of soybean hulls-soybean meal based supplements on intake and performance of beef cows[a]

	1.4 lbs CP 6.2 lbs soybean hulls	1.4 lbs CP .1 lbs soybean hulls
Forage dry matter intake, lbs	14.8	16.4
Diet dry matter intake, lbs	22.6	19.9
Forage TDN, %	50.9	51.7
Diet TDN, %	55.1	56.3
Forage TDN intake, lbs	7.5	8.5
Diet TDN intake, lbs	12.5	11.2
Cow weight change, lbs	80[b]	41[c]

[a]Adapted from Marston et al., 1992a; Marston et al., 1992b.
[bc]Means within a row with different superscripts differ ($P < .05$).

Table 8. Effect of wheat mids-soybean meal based supplements on and performance of spring and fall calving beef cows[a]

	1.2 lbs CP 0 lbs wheat mids	1.2 lbs CP .8 lbs wheat mids	1.2 lbs CP 2.2 lbs wheat mids	1.2 lbs CP 4.9 lbs wheat mids
Supplement dry matter, lbs	3.0	3.75	5.0	7.5
Supplement TDN, lbs	2.4	2.8	3.6	5.1
Spring calving cows				
Weight change, lbs[a]	50[c]	68[cd]	89[d]	125[e]
Fall calving cows				
Weight gain, lbs[b]	-114	-119	-126	-102

[a]Adapted from Ovenell et al, 1989.
[b]Adapted from Cox et al, 1989.
[cde]Means within a row with different superscripts differ ($P < .05$).

High-quality forages also have application as supplements for mature low-quality forages. Data from New Mexico State University (Judkins et al., 1987) indicate that heifers grazing dormant rangeland responded similar to supplementation of alfalfa hay when fed at an equal level of protein as they did to cottonseed meal (Table 9). Heifers receiving no supplementation did not gain any weight in this trial. Other studies have indicated that alfalfa hay supplementation of low-quality forage is equal to soybean meal.

Table 9. Effect of alfalfa hay or cottonseed meal on performance of weaned heifers grazing dormant blue grama rangeland[a]

	No supplement	.8 lbs CP alfalfa hay	.8 lbs CP cottonseed meal
Supplement dry matter, lbs	0.0	4.0	1.9
Supplement TDN, lbs	0.0	2.3	1.5
Average daily gain, lbs	-.07[b]	.51[c]	.53[c]

[a]Adapted from Judkins et al., 1987.
[bc]Row means with different superscripts differ ($P < .05$).

High-quality grass forage also can be used as supplements. In a study (Villalobos, 1992) conducted at Gudmundsen Sandhills Laboratory with cows grazing dormant native range, cows supplemented with .7 pounds of protein from either high-quality meadow hay or soybean meal gained more weight than cows receiving no supplement (Table 10). The cows receiving 4.8 pounds of high-quality grass hay gained more weight than cows receiving an equal amount of protein from soybean meal. The native grass hay supplied an estimated 2.8 pounds of TDN, while the soybean meal supplement supplied an estimated 2.2 pounds of TDN, and the increase in gain (.2 pounds/day) of the cows receiving the hay supplement may have been due, in part, to the increase in the TDN intake from the supplement. The hay supplement may also have had a greater positive associative effect on the utilization of the base forage.

Table 10. Effect of high-quality meadow hay or soybean meal on performance of cows grazing sandhills winter range[a]

	No supplement	.7 lbs CP grass hay	.7 lbs CP soybean meal
Supplement dry matter, lbs	0.0	4.8	2.6
Supplement TDN, lbs	0.0	2.8	2.2
Weight gain, lbs	-54	80	56
Condition score change	-1.2	.1	.1

[a]Adapted from Villalobos et al., 1992. Data averaged for two studies.

MEDIUM- AND HIGH-QUALITY FORAGES

The effect of supplements high in non-structural carbohydrates on utilization of medium- and high-quality grass forages are different than with mature low-quality low-protein forages. Table 11 shows data collected from digestion trials with sheep fed low-, medium-, and high-quality forages with increasing levels of corn (Sanson, unpublished data). The data have been adjusted to represent a 1000-pound cow, however, because of differences in intake patterns between cattle and sheep and potential differences in digestibility between the species, values may be higher than would be expected with cattle. The data are presented only to show the differential effects of corn on different qualities of forage. With the low-quality forage, forage intake and forage TDN were decreased by the higher levels of corn, and diet TDN intake was increased by 1.9, 2.2, and 3.3 pounds when 2.3, 4.5, and 6.8 pounds of TDN from corn was fed. With the medium- and high-quality forage, forage TDN was not altered or slightly improved as level of supplemental corn increased. Diet TDN intake was not increased with the higher levels of corn.

Table 11. Effect of corn on intake and digestibility of native meadow hays of three qualities by sheep (data adapted for 1000 lb cow)[a]

	No supplement	1.4 lb CP 0.0 lbs corn	1.4 lbs CP 2.5 lbs corn	1.4 lbs CP 5.0 lbs corn	1.4 lbs CP 7.5 lbs corn
-------- Mature low-protein (5.2%) native meadow hay --------					
Forage dry matter intake, lbs	20	24	24	23	20
Diet dry matter intake, lbs	20	26	28	30	29
Forage TDN, %	41.8	45.7	47.5	42.7	42.0
Diet TDN, %	41.8	47.7	51.1	48.8	54.3
Forage TDN intake, lbs	8.4	11.0	11.4	9.8	8.4
Diet TDN intake, lbs	8.4	12.4	14.3	14.6	15.7
-------- Vegetative medium-protein (10.2%) native meadow hay --------					
Forage dry matter intake, lbs	27	24	22	22	18
Diet dry matter intake, lbs	27	27	27	29	27
Forage TDN, %	56.1	59.1	60.0	59.5	61.0
Diet TDN, %	56.1	59.8	61.4	62.3	63.9
Forage TDN intake, lbs	15.1	14.1	13.2	13.1	10.9
Diet TDN intake, lbs	15.1	16.1	16.6	18.1	17.2
-------- Vegetative high-protein (10.2%) native meadow hay --------					
Forage dry matter intake, lbs	28	29	26	23	19
Diet dry matter intake, lbs	28	31	30	30	29
Forage TDN, %	56.8	59.1	60.7	62.3	62.7
Diet TDN, %	56.8	59.8	62.0	63.9	65.6
Forage TDN intake, lbs	15.9	17.1	15.8	14.3	11.9
Diet TDN intake, lbs	15.9	18.5	18.6	19.1	19.0

[a]Data adapted from Sanson, 1993 (unpublished data). This trial was conducted with lambs and has been adapted for 1000 lb cow. Because of intake differences by sheep and cattle, values may be higher than expected with cows, however the general differences among hays should apply.

In a trial conducted at the University of Wyoming (Sanson et al., 1993), heifers fed a medium-quality (8.5% protein) native meadow hay and supplemented with either 1.5 or 3 pounds of corn or barley gained more weight than heifers receiving no supplement (Table 12). Although mean weight gains for the two levels of corn supplementation were the same, the statistical analysis indicated that as both corn and barley supplementation increased, heifer gain increased linearly. Estimated supplement TDN supplied by the low and high levels of corn and barley was

1.4, 2.7, 1.3 adn 2.5 pounds, however statistical analysis indicated that there was no difference in utilization of either corn or barley when supplemented at similar dry matter levels.

Table 12. Effect of corn or barley on performance of heifers consuming medium-quality (8.5% protein) native meadow hay[a]

	No supplement	.15 lbs CP 1.5 lbs corn	.30 lbs CP 3.0 lbs corn	.19 lbs CP 1.5 lbs barley	.39 lbs CP 3.0 lbs barley
Supplement dry matter, lbs	0.0	1.5	3.0	1.5	3.0
Supplement TDN, lbs	0.0	1.4	2.7	1.3	2.5
Weight gain, lbs[b]	1.0	1.4	1.4	1.3	1.6
Condition score change	.1	.2	.0	.2	.2

[a]Adapted from Sanson et al., 1993.
[b]Linear effect of corn and barley ($P < .05$).

Assigning a quality value for a forage is difficult. In a trial conducted at the Gudmundsen Sandhills Laboratory (Sanson and Clanton, 1989), cows consuming a native meadow hay containing 7% crude protein and either 2, 4, or no corn resulted in similar performance, although there was a trend for increase in gains as level of corn supplementation increased (Table 13). This hay was selected for this study to represent a mature low-quality hay, however later evaluation of the digestibility of the forage indicated that the TDN value of the forage was approximately 51%. That combined with the performance of the animals on the hay indicates that this hay responded more like a medium-quality forage.

Table 13. Effect of corn on performance of cows consuming medium-quality (7.0% protein) native meadow hay[a]

	No supplement	.2 lbs CP 2 lbs corn	.4 lbs CP 4 lbs corn
Supplement dry matter intake, lbs	0.0	2.0	4.0
Supplement TDN intake, lbs	0.0	1.8	3.6
Forage dry matter intake, lbs	23	20	20
Forage TDN intake, lbs	11.7	10.2	10.2
Weight gain, lbs	20	23	28

[a]Adapted from Sanson and Clanton, 1989.

TYPES OF SUPPLEMENTS

Although supplements can be classified in many different ways, from a nutrient standpoint they are usually classified as either protein or energy supplements. This classification causes confusion since both protein and energy supplements supply both protein and energy.

Table 14 lists some common ingredients that are used in supplements. Note that the energy content varies from 58 to 90% TDN, while the protein content varies from 10 to 50%. Because of difference in associative affects that supplements have on forages of various qualities, it may be more appropriate to classify the feeds by their non-structural carbohydrate content than by either protein or energy.

Table 14. Energy and protein composition of some feeds commonly used in supplements[a]

	TDN, %[b]	ME, Mcal/lb	CP, %
Grains			
Corn	90	1.47	10.1
Barley	84	1.38	13.5
Oats	77	1.26	13.3
Sorghum	84	1.38	10.1
Wheat	88	1.44	16.0
Oil seed meals			
Cotton seed meal	80	1.31	45.6
Soybean meal	84	1.38	49.9
Canola meal			42.2
Other feeds			
Alfalfa hay	.58	.95	18.0
Beet pulp	74	1.22	9.7
Molasses	72	1.17	5.8
Soybean hulls	64	1.05	12.1
Wheat bran	70	1.15	17.1

[a]Values from NRC, 1984.
[b]Values are on a dry matter basis. If fed on an as-fed basis, these values should be adjusted for the amount of moisture. On an as-fed basis, assuming 88% dry matter for corn and 75% dry matter for molasses, corn would have 79% TDN and molasses would have 56% TDN.

All of the feeds in Table 14 provide both energy and protein. The grains are fairly low in protein, ranging from 10 to 16% protein, while the oil-seed meals are high in protein, ranging from 42 to 50%. The energy content of both the grains and oil seed meals are fairly close, ranging from 80 to 90% TDN. These two types of feed also vary in their carbohydrate structure. The grains are high in non-structural carbohydrates (starch and other rapidly degraded carbohydrates), while the oil seed meals are low in these compounds. The third group of feeds are more variable in their energy and protein content. These feeds also vary widely in their non-structural carbohydrate content. Beet pulp, alfalfa hay, and soybean hulls are relatively high in structural carbohydrates, however these carbohydrates are highly digestible. Wheat mids contain more starch (a non-structural carbohydrate) but also contain some highly degradable fiber or structural carbohydrates. The level of starch may or may not be high enough to cause a problem, depending on the forage quality as well as other factors. The carbohydrate fraction of molasses would essentially be all non-structural carbohydrates and would be expected to have the negative associative effects similar to those that occurs when mature low-quality forages are supplemented with grains.

Table 15 shows the TDN content of supplements formulated using soybean meal and some of the grains and high-fiber feeds from Table 1. Two supplements were formulated for each of the feeds, one containing 20% crude protein and one containing 40% crude protein. With the grains, the energy content varies little between the 20 and 40% crude protein supplement. For example, with the corn-soybean meal supplement containing 20% protein, the TDN value is 89% whereas with the 40% supplement, the TDN value is 86%. The protein content of the supplement doubled, yet the TDN content changed only 3%. Since the TDN used in formulating the barley and sorghum supplements is the same as that of soybean meal, there is no difference in the TDN content of the 20 and 40% supplements formulated with these grains. The TDN content of the soybean hulls and alfalfa hay supplements varies more between the 20 and 40% supplement. This variation is because the TDN content of soybean meal is higher than either of the two high-fiber feeds.

Table 15. TDN concentrations of some feeds used in formulating 20 and 40% protein supplements using soybean meal

	20 % Crude protein			40% Crude protein		
	TDN	1.5 lbs[a]	3.0 lbs[b]	TDN	1.5 lbs	3.0 lbs
Corn	89	1.33	2.66	.86	1.29	2.58
Barley	84	1.26	2.52	.84	1.26	2.52
Soybean hulls	68	1.02	2.04	.79	1.18	2.36
Alfalfa hay	.60	.90	1.80	.76	1.14	2.28

[a]Amount of TDN supplied by 1.5 lbs of dry matter.
[b]Amount of TDN supplied by 3.0 lbs of dry matter.

As shown in Table 15, all supplements provide both protein and energy. When feeding 1.5 pounds of the 20% corn/soybean supplement, 1.33 lbs of TDN and .3 pounds of protein are provided. Feeding 1.5 pounds of the 40% corn/soybean meal supplement, 1.29 pounds of TDN and .6 pounds of protein are provided. Feeding the same amount of dry matter of the two corn-based supplements result in similar levels of TDN provided, however with the 40% protein supplement, twice as much protein is provided. In general, this statement holds for all the supplements shown in Table 15. With the alfalfa hay and the soybean hulls-based supplements, there is a little more TDN fed with the 40% supplements.

This discussion should not be taken to mean that there is little difference in the energy value of the supplements. There is variation in the energy content of the supplements in Table

15, as the base ingredients change. Most supplements are formulated using some form of least cost formulation, and the ingredients may change from batch to batch. Some ingredients are better sources of energy and/ or protein than others. Also, the addition of minerals, vitamins, and non-protein nitrogen do not contribute energy to the supplement, resulting in lower energy values.

SUMMARY

The data in this paper implies that the type of associative effect that a supplement will have on the forage is dependent on both the ingredients of the supplement and the quality or maturity of the forage. In choosing a supplement, forage quality and, if possible, the ingredients of the supplement should be known. Supplements high in non-structural carbohydrates have a negative effect on utilization of mature, low-quality forages; the amount of negative effect depends on forage quality, amount of supplement fed and the grazing conditions. In contrast, with mature, low-quality forages, protein supplements low in non-structural carbohydrates have a positive associative effect and will increase both forage intake and the TDN value of the forage. Associative effect of supplements high in non-structural carbohydrates on medium- and high-quality forages do not appear to be as negative as with mature forages and the effect on forage intake appears to be a one to one substitution.

The discussion in this paper should not imply that corn or other grains should never be fed with mature forages. In situations where forage is in short supply, it may be more economical to discount the TDN value of the forage and to use grain to provide the additional energy. In all situations, it should be realized because of associative effects of supplements on forage utilization, use of traditional methods to calculate energy intake that do not correct for associative affects by either increasing or decreasing energy value of the forage, and adjusting for intake of the forage may result in error. In any nutrition program, condition score of the cows or a random group of the cows should be evaluated throughout the feeding period to ensure that the feeding program is actually providing the level of nutrients required.

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